Can Parrots Be Conserved through Sustainable Harvesting?

A new model for sustainable harvesting regimes when biological data are incomplete

Steven R. Beissinger and Enrique H. Bucher

Neotropical parrots have become one of the most threatened groups of birds in the world, primarily as a result of habitat destruction and international trade. An immediate halt to the international trade of parrots is urgently needed to reverse the declines of many species, but habitat conservation is also required. Sustainable management could potentially achieve both. We propose a conservative model for harvesting parrot nestlings that requires the exploiter to make an environmental investment. When a local population is stable or growing, increases in population size due to management programs would be harvestable.

Can sustained harvesting be implemented to conserve parrot populations, given that many parrots are currently overexploited? Biological data suggest that there is a good potential to harvest some parrots in a sustainable manner, but only if harvesting is implemented using site-specific quotas in place of the current system of national quotas. The approach we suggest is unlikely to lead to overharvesting, can be initiated in the absence of all of the knowledge needed to set harvest quotas, and should lead to habitat protection. Although this approach is intended to avoid some of the pitfalls that have plagued other sustained-harvest schemes, substantial social, political, and economic difficulties still lie in the way of implementing sustainable-harvest schemes with parrots. In this article, we explore the biological potential for applying sustained-yield approaches to parrots, and we examine the social, cultural, and political conditions that must be controlled if sustained-harvest approaches are to result in successful conservation.

Regulation of parrot harvesting will be needed on the national and international levels

Steven R. Beissinger is an associate professor of wildlife ecology at the School of Forestry and Environmental Studies, Yale University, New Haven, CT 06511. Enrique H. Bucher is a professor and director of the Center for Applied Zoology, University of Cordoba, Cordoba 5000, Argentina.

Threatened parrot populations

Vast quantities of New World parrots have been exported from Third World countries to First World countries during the past two decades, primarily to supply the pet trade and private aviculturists. More than 1.8 million parrots legally entered the international trade from 1982 to 1988, mostly imported into the United States (80%), the European Common Market countries (15%), and Japan (3%; Thomsen and Mulliken 1991). Estimates of parrot mortality before exportation and the magnitude of illegal smuggling indicate that the number of birds removed from the wild was actually two to three times as great as these estimates (Inigo-Elias and Ramos 1991, James 1991).

At least 30% of the 140 parrot species found in the Western Hemisphere are now threatened with extinction, making neotropical Psittacidae one of the most threatened groups of birds in the world. Recent figures suggest that 40% of these species are threatened primarily by habitat destruction, 17% primarily by trade, 36% by a combination of the two causes, and 7% by other factors (Collar and Juniper 1991). Furthermore, populations of most of the 98 parrot species that are not considered threatened are currently thought to be declining.

Figure 1 shows how the dual but separate effects of habitat destruction and direct exploitation for the pet trade have led to drastic population declines of most New World parrots. Habitat destruction has occurred at an accelerated rate during the past two decades and has led to deforestation of large areas (FAO/UNEP 1981, Myers 1991). Land-tenure problems on both public and private lands facilitate unrestricted exploitation of forests and wildlife. Severe nesting habitat destruction is caused by local *campesinos* (local peoples) who destroy the nest cavity (Figure 2) or even cut the tree to gain access to nestlings (Beissinger and Bucher 1991). These conditions are perpetuated by the lack of land tenure for *campesinos* and a lack of expertise to implement sustainable exploitation schemes that might offer a viable alternative to the current unsustainable exploitation. The combined action of these factors on parrots is the simultaneous loss of nest cavities, which are usually in short supply and limit parrot reproduction (Beissinger and Bucher 1991), and a decrease of foraging habitats.

The profit motive, parrots' pest status, and lack of biological information have resulted in unsustainable levels of parrot exploitation. Parrots have recently become fashionable as pets in Europe and the United States (Figure 1). In response, the demand for neotropical parrots has risen greatly from less than 100,000 parrots legally traded annually in the 1970s (Roet et al. 1981) to more than 250,000 in the 1980s, even though fewer countries were exporting birds in the 1980s (Thomsen and Mulliken 1991).

This increased demand has transformed the trade into a more profitable business. For example, a *campesino* in the Chaco savannas of Argentina receives $7 for each blue-fronted Amazon fledgling (*Amazona aestiva*), but the bird then sells for approximately $400 in a pet store in the United States (Bucher in press).

Because parrots occasionally eat crops, in some countries (e.g., Argentina) all psitticines are considered pest species, although such status is unjustified (Bucher 1991). And because little reliable information on the population biology of most parrots exists, export quotas cannot be set rationally (Thomsen and Mulliken 1991).

The first step to halt the declines of many parrot species is for consumer countries to legislate a ban or a time-limited moratorium on the importation of parrots. Even though all exporting countries are members of the Convention on International Trade in Endangered Flora and Fauna (CITES), and many exporting countries have adopted trade regulations, the domestic and international laws that are supposed to ensure that trapping for trade does not result in species declines have been largely ineffective (Thomsen and Mulliken 1991). Current numbers of wild-caught parrots being imported for commercial activities are indefensible, and the sale of these birds must be stopped as soon as possible. Legislation to stop the importation of wild birds is currently being considered in the United States (West 1991) and Europe (Knights and Currey 1990).

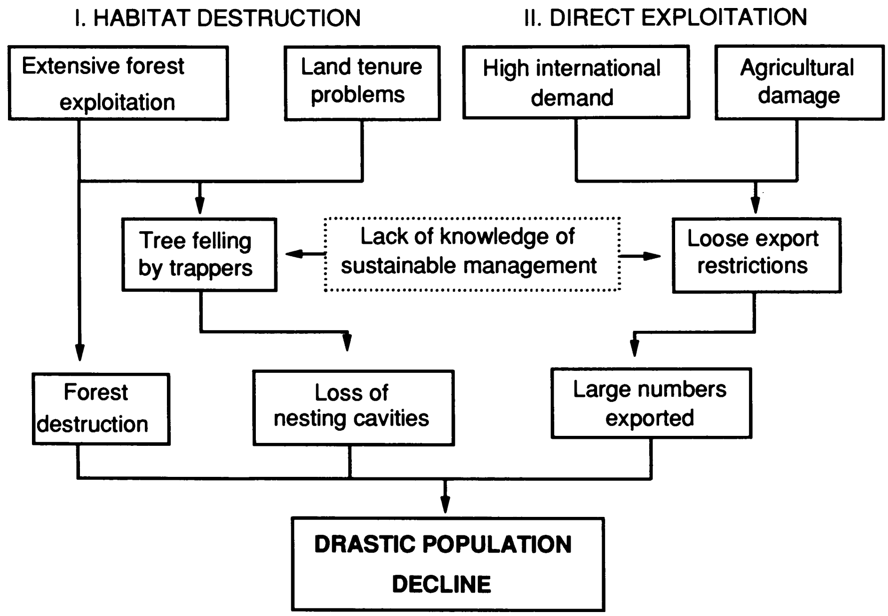

Figure 1. The dual, separate causal chains that have led to drastic population declines of neotropical parrots through habitat destruction and exploitation for the pet industry. The proximate causes of the demise of parrots toward the bottom of the figure are driven by the ultimate factors at the top. A poor understanding of sustainable practices connects both chains. Both chains must be broken if conservation efforts are to be successful. (After Bucher in press.)

Even with a total import ban in place, a high international demand may still result in poaching and smuggling of parrots. And, although captive breeding of parrots to supply the pet trade will probably increase in developed countries as a result of a ban, none of the revenues would reach peoples in the countries of origin of these birds or would be channeled into habitat conservation. In addition, an import ban would not decrease the rate of habitat destruction due to forest exploitation or stop the internal trade in parrots, which is substantial in some countries (James 1991).

The causal chains of Figure 1 must be broken by a decrease in both direct exploitation and habitat destruction. But, a poor understanding of sustainable practices connects both causal chains and afflicts policies related to the regulation of both forest exploitation and the levels of direct exploitation of parrots.

Sustainable management

Sustainable management offers one approach to breaking both causal chains. Sustainability is the continued

Figure 2. A parent blue-and-yellow macaw (*Ara ararauna*) in the Manu Biosphere Reserve in Peru stands guard at the opening of its nest, which contains one nestling. The nest was located about 15 m above the ground in a cavity that was formed when the crown of a dead palm (*Iriartea ventricosa*) snapped off. Photograph by S. R. Beissinger and C. A. Munn.

persistence and replenishment of a resource despite use. In developing countries with growing populations and economic needs, large-scale preservation efforts like national parks and reserves are important means of ecosystem and species preservation, but they are becoming increasingly difficult to enact and the great majority of the land area will likely remain in private ownership.

In the face of development pressures, conservationists have been exploring ways to conserve resources by using them. Land uses that integrate conservation and development in a sustainable manner, such as extractive reserves where latex and other plant products are harvested from primary forest instead of timber (Fearnside 1989, Peters et al. 1989), deserve consideration as alternative conservation strategies. In developing countries, programs to harvest wild animals sustainably may take the form of ranching. For example, game ranches in Africa (Bothma and Du Toit 1989) and iguana (*Iguana iguana*) ranches in Central America (Cohn 1989, Werner 1991) provide wild meat for markets or local peoples.

Sustained harvesting of parrots might benefit their conservation. Because regulated harvesting of wildlife can result in sustainable land-use practices on private lands, such harvesting may be complementary to, rather than incompatible with, land protection offered by national parks and reserves (Shaw 1991). Furthermore, sustained harvesting teaches conservation to local people and encourages them to participate in ecologically sound management.

Infeasibility of traditional sustained-yield management

To be sustainable, populations of wild animals must be harvested at a rate approximately equivalent to the productivity of the population, so that overall numbers remain approximately stable (Caughley 1977). Population models based on the concepts of maximal sustained yield or optimal sustained yield have been used to determine regional or national quotas for harvest levels of fish and game animals that are intensively harvested (Caughley 1977, Getz and Haight 1989).

Most managed species are harvested as adults: wildlife hunted as sport (e.g., deer and game birds), fish from commercial fisheries, and shellfish. Theories of harvesting often assume that population growth is logistic with some carrying capacity (K) for any habitat. In the simplest situation, the annual harvesting rate (h) will depend on how much the annual birth rate (b) exceeds the annual death rate (d). If harvesting is to be sustainable, then

$$(b - d)N - hN > 0.$$

Harvesting regimes should first set the population size (N) at levels where annual recruitment of the harvested age class (e.g., adults) will be maximized, and then the regimes

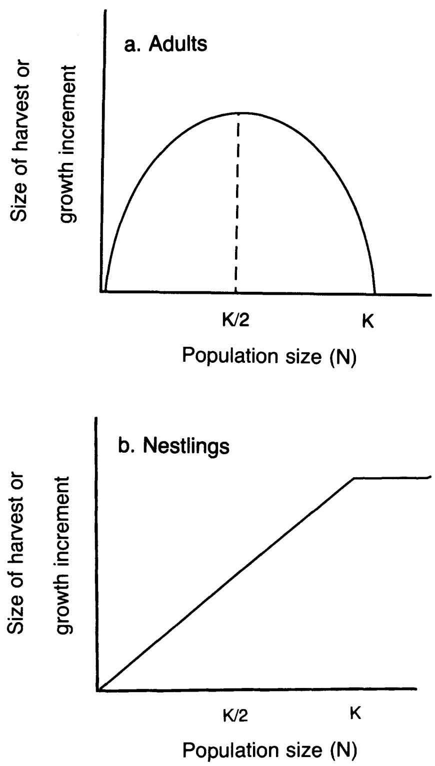

Figure 3a. The traditional sustained-yield model for harvest of adults, assuming that population growth is logistic. The maximum sustained yield occurs at intermediate densities near or just above one-half of the carrying capacity (K) of the environment. **b.** A hypothetical sustained-yield model for harvesting parrot nestlings. Productivity of the population is maximized by maximizing the number of occupied nest sites, so maximal sustained yield occurs near K.

should determine the appropriate number of individuals to harvest to remain at that density (Caughley 1977). When harvesting is concentrated in adults, the greatest annual growth increment occurs where the logistic growth curve rises most steeply near intermediate densities at approximately $0.5K$ or somewhat higher (Clark 1976), which results in the traditional parabolic sustained yield model (Figure 3).

Determining the parameters to set sustainable-harvesting levels requires a detailed understanding of the biological machinery that limits and regulates a population. Most of this information should be obtained before harvesting commences; other information can be gathered later, in conjunction with limited harvesting.

Six areas of biological knowledge are needed to harvest sustainably any animal (Beissinger and Bucher 1991):

- Population size and range. Minimally, population trends must be detected. Ideally, population densities would be assessed and these densities would be measured for different habitat types or land uses so that the effects of land conversion can be evaluated.
- Habitat requirements. These requirements are determined by the interaction of breeding and feeding requirements, and each must be assessed seasonally because changes may occur. Understanding diet, habitat requirements, and ranging behavior is critically important to assess the effects of landscape-level processes on population viability.
- Resilience to human disturbance and habitat changes. Human activities may have both direct and indirect effects. Direct effects (e.g., a bird's abandonment of a nest if it is visited by humans too frequently) can usually be kept at tolerable levels with proper knowledge of an animal's behavior. More significant are the effects of indirect disturbance that result from changes in land use. From subtle shifts in regional agricultural practices or cattle grazing to massive changes through deforestation, land-use practices often dramatically alter the natural vegetation and consequently may decrease or increase the carrying capacity of a species.
- Mortality and productivity rates. The harvesting potential of a species

is determined by age-specific natality and mortality rates and by the ages of first breeding and senescence. Demographic studies should ideally last for at least the lifespan of one cohort. However, some shortcut methods may be scientifically acceptable, such as stage-based demographic models (Caswell 1989, Getz and Haight 1989) that lump age classes into fewer groups and that can be used when age-specific information is lacking.

- Key factors. There are key factors that regulate populations and determine their tendency to increase or decline. The demographic traits that control population numbers can be determined through correlation analyses using several annual life tables (Varley and Gradwell 1960). Once identified, key factors may be managed to increase productivity or survivorship.
- Effects of environmental variation. Annual differences in weather can strongly affect productivity and survivorship (e.g., Bayliss 1989, Beissinger 1986). In such cases, average demographic traits may lead to faulty harvesting decisions (Bayliss 1989) because averages are less meaningful than the extremes. Because environmental extremes sometimes occur cyclically, for example rainfall-related phenomena, long-term data can be analyzed for predictability and cyclic trends (Beissinger 1986) to begin to understand how populations may be expected to fluctuate.

Considerable biological information will be needed to sustainably manage an animal population, and much of this data is difficult to obtain. The population biology of all parrots is too poorly known to calculate yields for even a single species. In fact, few parrots have received enough study to satisfy the requirements of any one of the six necessary areas.

Biological knowledge of this group is poor in part because most species are difficult to catch and band, have large home ranges, are tropical forest dwellers (so they have received little attention from ornithologists until recently), and nest in elevated tree cavities that are difficult to observe or reach. Furthermore, because most parrots are long-lived and reproduce at relatively slow rates (often they lay small clutches, raise only one brood per year, and delay the age of first breeding; Forshaw 1989, Snyder et al. 1987), the measurement of demographic rates will require at least five years for small parrots and ten years for large parrots. Such slow-reproducing and long-lived species typically are the most sensitive to the effects of overharvesting (Bucher 1991).

In addition, employing traditional maximal or optimal sustained-yield harvest regimes has been the subject of much debate (Clark 1976, Larkin 1977). Overharvesting has often been cited as the greatest problem in sustained-yield harvest programs (Dodd 1979, Vasquez and Gentry 1989) and often is fueled by a lack of scientific information needed to set harvest quotas. Even in developed countries and with organisms whose biology is relatively well known, attempts at traditional sustained harvesting (e.g., waterfowl hunting) have had problems preventing population declines (e.g., Rusch et al. 1989).

Harvest rates based on life-table calculations must be considered with caution because parameter estimates may change in a density-dependent manner; emigration and immigration may greatly affect the results; frequently, the age distribution of a population is not stable because of environmental fluctuations (life-table models assume a constant environment); and differences in productivity between habitats may alter the predicted recruitment dramatically.

Regulating trade by using traditional sustained-yield models to develop national quotas for harvesting parrots, as the trade is currently conducted, would not avoid these problems. Furthermore, using national quotas to regulate harvests does not tie harvest levels into local conditions and provides no impetus for ecosystem conservation. Harvesting of parrots is often done for extra income by *campesinos*, who do not own the land, or by poachers. The landowners (public or private) are missing actors in the parrot trade and have no motivation for preserving wildlife as a source of income.

The current situation leads to the "tragedy of the commons" (Hardin 1968): parrots are overexploited because they are viewed as nobody's property and their use is not locally regulated. The middlemen, buyers, and importers who profit most from the bird trade (Thomsen and Brautigam 1991) do not make investments to ensure the sustainability of the parrot trade in the region. Instead, they behave opportunistically and move to less exploited areas or shift to other species according to availability and international prices. Thus, using national quotas to regulate harvests benefits most those economic interests that lie outside of the region and that lack any commitment to sustaining the birds or their habitats.

Harvesting excess produced by management

Some of the problems resulting from the sustained-harvest approach might be overcome if there was a way to conserve habitats through sustained harvesting, yet minimize the risks of overharvesting. We suggest a conservative approach to sustained use that is unlikely to lead to overharvesting and can be initiated while the biological data are still incomplete. Rather than attempting to develop quotas for a region or country, the approach we advocate is site specific and would be used to set a harvest level for a particular ranch or management area.

We propose the conservative sustained-harvest model that we first developed for harvesting parrot nestlings (Beissinger and Bucher 1991): if it can be demonstrated that a local population is stable or growing—that is, $(b - d)N > 0$—then any increase in the rate of population growth due to management programs (m) would lead to an increase in overall population size (mN), which would be harvestable ($mN = hN$). Managers would need to document natural population trends on their land before or during the start of intensive management programs. Once management begins, the excess individuals produced from the increased rate of population growth could be harvested, and this procedure should result in the maintenance of the population at preharvest levels. At the same time, population sizes or trends must also be monitored on a continuing basis to ensure population stability (Beissinger and Bucher 1991).

The conservative sustained-harvest model is a cautious approach to sustained use of a resource. Because natural levels of productivity and population size are maintained, it is unlikely that this approach would lead to gross overexploitation unless initial populations were small. In such cases, population size should be increased first by increasing productivity and/or by decreasing mortality, and harvesting should not be attempted until much larger population sizes are achieved. This model is also useful for setting harvesting regimes in the absence of complete biological knowledge needed for initiating a sustained-harvesting program, because it permits some harvesting to be done while gathering the necessary data to obtain better estimates of demography and population-regulating factors for developing more sophisticated harvest models.

Another advantage of this approach is that the conservative sustained-harvest model requires the exploiter to make an investment in the environment (to improve its quality) and allows only the dividend (the increase in population growth) to be reaped. Harvesting the excess produced by enhancing habitat quality should lead to ecosystem conservation by giving impetus to restore or improve habitats. The site-specific emphasis of this approach should result in local conservation as long as economics favor sustainable-harvesting schemes.

This model is expected to be most useful with species whose productivity or survival can be greatly influenced by short-term management activities. For example, caiman populations in the plains of Venezuela appear to be limited by recruitment into the population (Thorbjarnarson 1991). Mortality is due both to predation of eggs in nests and to predation or starvation of young during the dry season, when they are concentrated with adults in the few areas that remain wet. Caiman ranchers have tried to increase productivity by rearing young hatched from eggs collected from the wild and then releasing them back into the wild after they have attained a size at which survival is more likely. Another way to increase juvenile survivorship would be to increase the number of ponds that hold water through the dry season. Both management methods are expected to result in an increase in population size that, under the conservative sustained-harvest model, could be harvested.

Applying the model to parrots

In applying the conservative sustained-harvest model to parrots, it is first necessary to determine what age classes should be harvested. Adult parrots frequently make poor pets because they are difficult to tame, may have trouble adapting to captivity, and often bring a lower market price than hand-tamed birds (Thomsen and Brautigam 1991). In contrast, young parrots removed from nest sites, hand-reared, and tamed generally make good pets, and consequently they are more valuable in the trade. Harvesting nestlings instead of adults also has less impact on wild populations because nestlings generally have relatively low survival rates and hence a low reproductive value (Fisher 1930). It may be possible to harvest the surplus of juveniles that would be expected to die before reaching breeding age (e.g., Potts 1986). Therefore, nestling parrots can probably be harvested in greater numbers than adults from the same population.

Because nestlings are preferable to adults for harvesting, maximizing parrot sustained harvests operates on a different model than traditional game-harvesting regimes (Figure 3). When harvesting nestlings, productivity (bN) and yield (bN) are maximized by maximizing the number of occupied nest sites. Therefore, a parrot population would not have to be reduced to approximately 1/2 K to maximize productivity and yield, as in the case of harvesting adults using a traditional sustained-yield model (Figure 3), but instead productivity and yield may be maximized at or close to K. Thus, sustainable harvesting of parrot nestlings, if properly done, would result in robust wild parrot populations.

Productivity can be maximized by intensive management of the factors that limit population growth. Although little is known about the key factors that limit parrot populations, there are many potential ways to increase the productivity of parrot populations (Figure 4) by increasing the number or proportion of adults breeding (e.g., the number of active nests), the percentage of nests fledging young (nesting success), and the number of young fledged per nest (fledging success). Increasing productivity might be accomplished by adding nest sites or nest boxes (Beissinger and Bucher 1991, Snyder et al. 1987), increasing the food supply (Martin 1987), protecting nests from predators (Snyder et al. 1987), deliberate multiple-clutching of wild pairs if pairs will readily lay replacement clutches for clutches taken into artificial incubation (although multiple clutching has rarely been attempted with wild parrots; Snyder et al. 1987), and decreasing the loss of last-hatched young due to starvation, which often occurs in asynchronously hatching broods, by transferring eggs or chicks into nests to create more synchronously hatching young with a higher chance of raising all young (Beissinger and Stoleson in press, Beissinger and Waltman 1991).

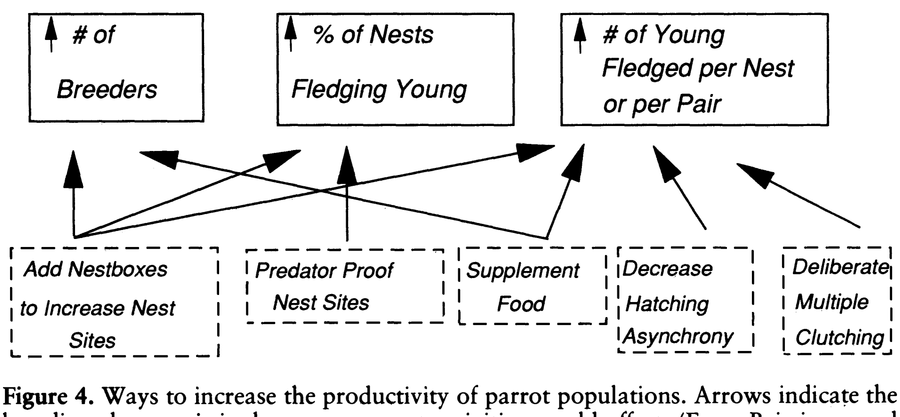

Figure 4. Ways to increase the productivity of parrot populations. Arrows indicate the breeding characteristic that management activities would affect. (From Beissinger and Bucher 1991.)

Of the above options to increase productivity from management activities, adding nest sites appears to hold the most promise. Limited abundance and access to nest sites can restrain adults from nesting and select for delayed breeding (e.g., Brawn 1987, von Haartman 1971). Studies of hole-nesting parrots (Beissinger and Bucher 1991, Munn 1991, Snyder et al. 1987) have documented large nonbreeding components of the populations (20% to 80% of the individuals). Contests between pairs to acquire and maintain ownership of nest sites are common and nest takeovers after infanticide are known to occur in parrots (Beissinger and Stoleson in press, Beissinger and Waltman 1991, Munn 1991). In addition, clutch size, fledging success, and nesting success often tend to be higher in nest boxes than in natural cavities (Korpimaki 1984, Moller 1989). If additional nest sites (e.g., boxes) are used by a population, or if forestry management practices were shifted to leave more snags for nesting cavities, then a significant increase in the number of birds nesting and the number of young fledging should be expected (Beissinger and Bucher 1991).

Evidence for increasing the productivity of a parrot population by adding nest sites comes from studies of the green-rumped parrotlet (*Forpus passerinus*). Although these small parrotlets typically nest in holes in tree boles or limbs and in termitoriums, recent studies in Venezuela found parrotlets nesting most commonly in hollowed fenceposts (Beissinger and Waltman 1991). An artificial nest box, designed from the dimensions of fencepost cavities and hung on fenceposts (Figure 5), rapidly replaced fenceposts as the most frequently used nest site.

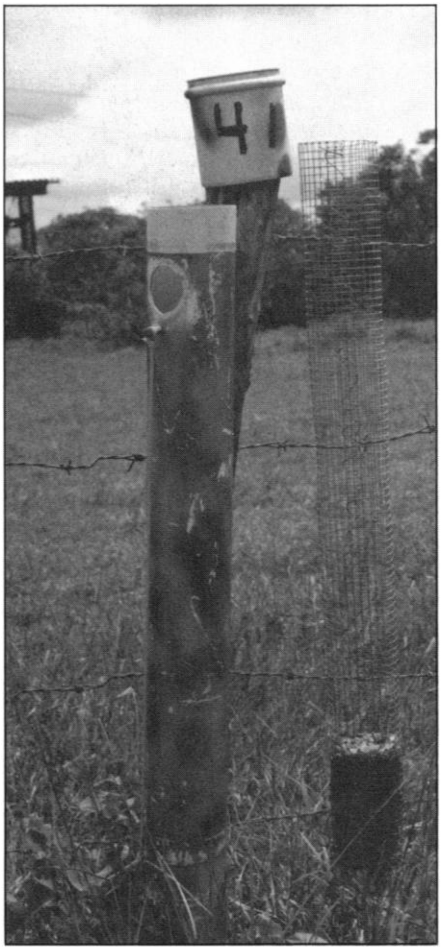

Figure 5. A nestbox used by green-rumped parrotlets (*Forpus passerinus*) hung on a fencepost at Hato Masaguaral in the llanos of Venezuela. The nestbox (one-meter-deep) was constructed from plastic polyvinylchloride (PVC) pipe with a removable inner sleeve of hardware cloth that the bird can use to climb. Eggs are laid on sawdust placed at the bottom of the box. Both the top and bottom of the box are removable. Photograph by S. R. Beissinger.

Almost every nest box (40 in 1988, and 100 in 1989 and 1990) was visited at least once by parrotlets during the past three breeding seasons. A total of 58, 119, and 151 nesting attempts in boxes were recorded during those years, whereas a total of only 14 to 17 nesting attempts occurred in fenceposts during the same three-year period. *F. passerinus* nests in boxes in 1988 and 1990 (years when nests were not affected by investigators' checks during egg-laying) were approximately 1.5 times as likely to fledge at least some young (66%, N = 195) than were nests in fenceposts from 1985 to 1990 (44%, N = 18). Also, nest boxes fledged significantly (Student's t-test = 2.5, $p < 0.05$) more young per successful nest (4.7 chicks) compared to nests in fenceposts (3.5 chicks). Although in the absence of controlled experiments it is difficult to estimate directly the increase in the number of green-rumped parrotlets breeding with the addition of nest boxes, several forms of indirect evidence suggest that the number of nesting pairs increased from 4 to 21 times (Beissinger and Bucher 1991).

From the above data, we can estimate the magnitude of excess production (mN) for sustainable harvesting under the conservative sustained-harvest model for *F. passerinus* by estimating what proportion of young produced from 100 nest boxes would have been produced under natural conditions (Beissinger and Bucher 1991; Figure 6). The most conservative estimate of harvestable young would assume that all birds nesting in boxes would otherwise have nested in natural nest sites if nest boxes were not available. Even using this unrealistically high estimate of the number of natural nests (Figure 6), nest boxes would produce an annual excess of 105 young, based on differences between fenceposts and nest boxes in nest success and fledging success rates. If, however, we assume that the density of nest boxes (16.3/km) has increased the availability of nest sites over that of potential nest sites found in fenceposts (4.5/km), nest boxes would produce 277 young annually in excess of natural production. Actually, only ten nest sites were found in fenceposts during the three years of study and if we assume production only from these known sites, harvestable annual production would be estimated at 284 young (Figure 6). Although the latter estimates may be in excess of what the population can support, the number of young that could be harvested sustainably should lie between 105 and 298.

Although the potential for a sizable sustained harvest by adding nest sites appears high for green-rumped parrotlets, are nest boxes likely to work with other species? Nest boxes are commonly used when breeding parrots in captivity, but they have only been tried a few times with wild populations of hole-nesting parrots. Nest boxes have been used on a limited basis by small parrots like the Blue-winged parrotlet (*Forpus xanthopterygius*)[1] and by larger parrots like the blue-and-yellow macaw (*Ara ararauna*; Munn 1991).

On the other hand, boxes received only limited use by Puerto Rican parrots (*Amazona vittata*; Snyder et al. 1987) and three other Amazona par-

[1]G. H. Katten, 1990, personal communication. University of Florida, Gainesville.

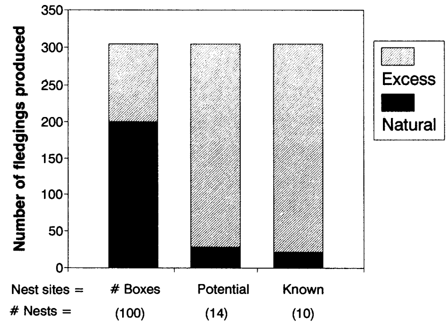

Figure 6. Estimates for sustained harvest of green-rumped parrotlets (*Forpus passerinus*) from 100 nest boxes based on different assumptions of the number of natural nest sites available in fenceposts. Sustained yield (excess) is the difference between the number of young actually produced in nest boxes and the number that would have been produced in fenceposts (natural). Productivity was estimated based on 1.3 nesting attempts per nest site or box, and conservative estimates for the percentage of nests fledging young from nest boxes and fenceposts (50% and 44%, respectively) and the number of young fledging per successful nest (4.7 and 3.5, respectively).

rots in Mexico (Perez and Eguiarte 1989). Nest sites may not have limited these populations, or the design or placement of the nest boxes might not have been attractive to the parrots. Although not all parrot species may be expected to accept nest boxes, and few may accept them as frequently as the green-rumped parrotlet, we suspect that nest boxes may be adopted to some extent by many parrot species.

Even though parrot populations appear to contain a large number of nonbreeding individuals (Beissinger and Bucher 1991), we caution against harvesting a large proportion of them because there are several indications that nonbreeders may play important roles in parrot societies. First, nonbreeders may act as social facilitators of breeding (Snyder et al. 1987). Many parrots forage in flocks and perhaps a threshold number of nonbreeding individuals is required to form foraging flocks. Foraging in groups can increase foraging efficiency and reduce the chance of being surprised by a predator while foraging (Powell 1974, Wescott and Cockburn 1988). Second, nonbreeders act as a population buffer against the effects of environmental variation. Overharvesting that depletes this buffer increases the chance that a population will greatly decline. Finally, it is not known for many parrot species whether individuals breed annually or less often. In species where breeders do not breed every year, nonbreeders in one year may be breeders in the next year. Thus, the role of nonbreeders in regulating parrot populations could be more important than otherwise might be suspected.

Social and political factors impede sustained harvesting

Solving the biological problems associated with the sustained harvest of wildlife may be far easier than solving some of the social and political problems that are inherent to sustained-harvest programs. Critics of the market approach to conservation have pointed out that problems in regulating harvesting and trade and stimulating the market economy past the limits of sustainable production have plagued the implementation of sustained-harvest programs that raise wild meat for markets through ranching schemes (Geist 1988) or that farm sea turtles (Dodd 1979, Ehrenfeld 1979). Because of these problems, successfully implementing sustained-harvesting programs with parrots is not expected to be easy.

It is unlikely that parrots can be sustainably harvested if large numbers of birds are being legally harvested in an unsustainable manner (as the trade is currently practiced). Unless laws can protect from overharvesting, or enforcement efforts make smuggling parrots much more difficult and costly, it will always be cheaper and easier to take birds from the wild in an unsustainable manner and sell them through legal or illegal channels than to harvest them sustainably. Implementing successful sustained-harvest operations may require both the passage of legislation to control the parrot trade and truly effective control over illegal harvests.

Strong regulation of trade has helped make successful sustained-harvest programs with butterflies and crocodiles in Papua New Guinea (NRC 1983a,b) and caiman in Venezuela (Thorbjarnarson 1991). In both cases, governments passed protective legislation that banned unlicensed commercial operations. Similar prohibitive legislation of trade in neighboring countries has made it difficult for products from outside the country to be laundered into the ranching system (NRC 1983b), a practice that sometimes occurs in the parrot trade (Thomsen and Mulliken 1991).

Regulation of parrot harvesting will be needed on the national and international levels. Within a country, each ranching program must be registered if it is to harvest birds. Trained biologists must visit each site to conduct surveys and research to help set harvesting levels. Similar site-specific programs have been implemented with caiman and butterfly ranching, where governments regulate the licenses of landowners and tanneries (NRC 1983a,b, Thorbjarnarson 1991).

Initially, some modest financial assistance from international conservation organizations may be needed to help organize the political structure and to train field biologists in parrot biology. Thereafter, a small tax on each bird harvested could support the program, as is the case for caiman harvesting in Venezuela (Thorbjarnarson 1991). An international commission may be needed to regulate the international bird trade and to set and enforce standards for harvesting operations.

Even if unlicensed commercial operations are outlawed, we expect regulatory problems to persist because maintaining a market for parrots may encourage the harvest of birds from outside the managed population. It will be especially difficult and important to protect the highly endangered, valuable amazons and macaws from illegal trade. Determining the source of nestlings is difficult, and cheating may be hard to detect. Although regulations can require all harvested chicks to be marked (e.g., banded with closed stainless steel rings), currently no identification system is completely reliable. Genetic, isotope, and mineral markers have been used to determine source locations of ivory and rhinoceros horns (Baskin 1991, Cherfas 1989, van der Merwe et al. 1990) and bird feathers (e.g., Hanson and Jones 1968), but these techniques appear to be applicable only in specific circumstances and may not work with parrots.

Nevertheless, strict but flexible harvest quotas should set a limit on the number of nestlings to be harvested. If a nestling that did not come from the managed population is sold in a sustained-harvest program, it would take the place of one that would have, and for ranching programs with fixed quotas the net result should be more or less the same. Sooner or later, overharvesting of this type should be detected through population monitoring, and then harvest limits could be lowered.

The maintenance of a market for parrots may also encourage the poaching of birds from sustained-harvest programs, if they can be sold on the black market. Ranching schemes on public land may be expected to have this problem more often than programs on private lands. Nest boxes may be especially vulnerable to exploitation by thieves because of the ease of finding and entering nests, although boxes placed relatively near each other may be easy sites to protect. Losses to poachers may be minimized by guarding nests from the time of hatching until harvest, which would increase the costs to producers. The long-term solution to the problem of poaching is to eliminate the black market by increased law enforcement efforts.

Finally, land tenure may be a major bottleneck for the rational exploitation of wildlife in Latin America, including managing parrot harvests sustainably. If the exploiters do not own the land, they may be unlikely to make investments for the future (e.g., allowing some young to fledge) to sustain parrot populations. Education programs targeted at people living in the management area could help to ease some of these conflicts and have led to successful sustained-harvesting programs on public lands in Africa (Lewis et al. 1990). But, it will be difficult for *campesinos* living on the edge of survival to forego the harvest of a portion of nestlings to increase future breeding productivity rather than maximize their immediate returns by harvesting all nestlings.

Thus, if harvesting is to become sustainable, it should be restricted to licensed commercial operations with site-specific quotas. To control the problems of overharvesting and smuggling of parrots, legislation must be passed to end the unsustainable harvests that have been fueled by the current practice of national quotas. Reliable marking systems must somehow be developed and tested to distinguish legally harvested birds. The temptation to overexploit when prices are favorable will always be strong, even though such exploitation may jeopardize the very existence of the market in the long run (Clark 1976). Implementing the conservative sustained-harvest model should help to offset the natural tendency to overharvest. But the costs of effectively regulating these problems may be beyond the available resources of many developing countries.

Can sustained harvesting be economically competitive?

The success of sustained-harvest programs ultimately depends on their economic feasibility. Birds harvested from sustained-management programs will have to compete in the marketplace with birds bred in captivity and with those harvested illegally. If legislation to protect birds is enacted, achieving control over illegal trade may take large investments in law enforcement and education, although it may be cheaper than outlawing trade altogether and trying to control poaching or smuggling (Lewis et al. 1990).

We suspect that parrots will be less costly to produce from sustained-harvesting programs in countries of origin than from captive breeding programs in developed countries, because birds produced in captive situations will cost much more to house and feed than birds produced from sustained-harvest programs (Beissinger and Bucher 1991, Clubb 1991). Other expenses (e.g., nest boxes and veterinarian fees) are common to both operations.

Costs associated with transporting or exporting birds (e.g., shipping, quarantine, and veterinarian fees) are likely to be significant for sustained-harvest businesses. It would be more practical for sustained-harvest operations to sell their birds directly to an exporting agency rather than exporting the birds themselves, because the exporter assumes the risks of losing birds to disease or death during the importation process. Parrot ranchers could form cooperatives that could arrange for the transportation or exportation simultaneously of all birds from sustained-harvest programs to reduce costs, eliminate the middle men, and increase profits.

Obtaining field information, guarding nests, and harvesting the young may be the largest, unique expenses incurred in sustained-harvest operations. But sustained-harvesting programs may be able to produce more young than most captive breeding facilities. For instance, the sustainable-harvest estimates for green-rumped parrotlets from an approximately five-kilometer-square portion of Hato Masagural in Venezuela (Figure 6) is more than the annual production of *F. passerinus* breeders in the United States.[2]

In the long run, sustained harvesting of parrots is most likely to succeed if it is part of a diversified set of products on a parcel of land that is being managed sustainably (e.g., cattle, latex, brazil nuts, selective logging, ecotourism, or other harvested wildlife). Under such circumstances, parrot ranching might provide extra income during years when other products are being produced, and it could play an important role in subsistence living during less profitable times. Diversifying income may be necessary for sustainable management to compete with schemes that simply maximize immediate returns.

A diverse, multispecific production system may also be necessary because the future of a market for sustainably harvested parrots is full of uncertainty (e.g., changes in demand and prices). First, the possibility exists that as a result of the campaign for enactment of a partial or complete ban of parrot importation, changes in public attitudes could render parrots less desirable as pets. On the other hand, restrictions are likely to increase the price of birds, thus making more feasible the sustained harvesting of parrots, because captive breeding has higher costs than does importing wild birds (Clubb 1991). Second, captive breeding will eventually increase in scope and efficiency, so the supply of birds should increase. Finally,

[2]R. Conser, 1991, personal communication. Private breeder, San Diego, CA.

many species of parrots are long-lived and the possibility exists for some degree of market saturation. These uncertainties in future prospects may tempt some managers and traders to maximize immediate returns instead of harvesting in a sustainable manner.

A trade moratorium to encourage sustainability

Realizing many of the benefits from sustained harvesting will require a degree of control over trade that currently is difficult, if not impossible, to achieve. In the absence of effective controls, attempts at sustained harvesting could exacerbate the conservation problems. Because of the urgency of the current situation (Collar and Juniper 1991), there is no rational choice but to halt the international trade in parrots until evidence can be presented that such trade in any species can be constituted in a sustainable manner.

Obtaining the biological and sociological data to conduct a sustainable trade will require large investments of time and money. Although we have demonstrated a potential for sustained harvesting, there is still much methodology to be perfected, parrot biology to be learned, and sociological research to be conducted before a generic recipe for sustained harvesting of parrots can be developed. Strong hopes should not be placed in sustained harvesting, by including it as part of the legislation (West 1991), until several demonstration projects can determine the feasibility and scale of sustained harvesting of parrots. But because a trade ban alone is unlikely to slow the high rate of habitat destruction that threatens most of these parrots (Figure 1) and other forms of biological diversity, legislation should be enacted in such a way that it will encourage future sustainable-harvesting schemes.

We recommend that importing countries and CITES adopt an immediate moratorium on the importation of parrots for a fixed time period, such as five years. The American Ornithologists' Union recently made a similar recommendation for the importation of all wild-caught birds into the United States (Beissinger et al. 1991). A moratorium on importation is preferable to the legislation for partial bans currently being considered by Congress (West 1991), because it would immediately reduce the detrimental effects of the trade on wild populations, be easy to enforce, and be cost effective.

During a moratorium, experimental sustained-harvesting programs could be run to find solutions to the problems of illegal laundering of birds, poaching, reliable marking systems, and overharvesting. A moratorium could be held open for limited importations of birds as part of internationally recognized scientific studies of birds in captivity, recovery efforts, or public exhibitions for educational purposes. At the end of the moratorium, trade could be reopened for selected species for which it can be shown that harvesting is sustainable.

Legislative initiatives should encourage a future for sustainable harvesting of parrots because, if it is implemented properly, sustainable harvesting may provide advantages for conservationists, aviculturists, the pet industry, and local peoples. Conservationists could gain by having wild parrot populations that are near carrying capacity and by transmitting economic value to habitats to help conserve them in their natural states. For example, if parrots can be sustainably harvested from tropical rainforests, this commodity might help to make extractive reserves more economically valuable than forest land cleared for timber harvest or cattle production (Peters et al. 1989).

Sustained harvesting of many species of parrots would require that substantial areas of land be maintained as mature forest. Aviculturists could obtain new genetic stock for their breeding programs from birds harvested sustainably. The pet industry would have a steady, small inflow of legally imported birds already conditioned to captivity. And, finally, the profits from these programs could be directed to the local people who are most in need of ways to support themselves.

If a conservative approach to sustained harvesting can lead to robust parrot populations and habitat preservation, then giving a market value to these birds will have achieved its purpose. Sustainable harvesting of parrots should be able to contribute to the conservation of parrots once we have obtained information on parrot biology, developed technologies to control and enforce harvesting and trade regulations, and incorporated parrot ranching within a diverse set of products being managed sustainably.

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